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14. ABSTRACT An array of 15 EM-APEX floats were deployed in northern Atlantic to investigate near-inertial waves modulated by mesoscale eddy field and to study seasonal variability of turbulence mixing driven by near-inertial waves and internal tides. Strong refraction of near-inertial waves by mesoscale vorticity gradient was observed and compared with theoretical results. In late summer through early spring, near-inertial/semidiurnal motions were energized in the surface mixed-layer and permanent pycnocline penetrated to 800-m after late summer and fall storms. Internal-wave vertical shear variance was ~5 times as energetic as canonical midlatitude (GM) internal waves. Clockwise-with-depth (downward energy propagation) shear dominates over this same period while counterclockwise-with-depth (upward energy propagation) shear dominates in late spring and early summer, and is correlated with major topographic ridges. Turbulent diapycnal diffusivities are $\sim 10^{-4} \text{ m}^2 \text{ s}^{-1}$, an order of magnitude larger than the canonical mid-latitude and exhibit factor-of-three month-to-month variability, consistent with the elevated internal-wave shear.					
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NISKINE DRI: Profiling Float Measurements of Near-Inertial Waves and Turbulence

ONR N00014-18-1-2598

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Long Term Goals

Our long-term goals of NISKINE DRI are to understand the generation of near-inertial and internal tides, and their subsequent propagation, interactions with meso- and submesoscale balanced flows, dissipation and mixing in the Sub-Arctic North Atlantic south of Iceland. Our primary instruments are EM-APEX floats. Specific goals are to

- relate the vertical and horizontal scales of the wind-forced mixed-layer motions to propagating near-inertial waves in the pycnocline;
- identify the dominant wave/mean flow interactions among Doppler-shifting, vorticity refraction and baroclinicity in the surface mixed-layer and pycnocline;
- determine how well the upper-ocean energy budget can be closed;
- quantify seasonal variability of stratification, subinertial eddy motions, near-inertial/semidiurnal fluctuations, and turbulent dissipation and mixing;
- identify sources of near-inertial/semidiurnal signals, e.g., wind vs. topography.
- identify sources of turbulence. Is turbulence driven by seasonal storms, local topography or both?

Work Completed

Toward these goals, 15 chi-augmented EM-APEX profiling float component were deployed 3 in coherent arrays of up to 8 continuously profiling floats during the June 2019 process-study cruise. There float measurements were conducted in conjunction with a Wirewalker and surface drifters to continuously profile to 400-600-m depth in mesoscale confluences, cyclones and anticyclones. Six floats were left behind for an extended mission to collect half-inertial-period (~7 h) pairs every 10-14 days to capture seasonal variability of the near-inertial/semidiurnal motions and turbulence for up to 22 months, until early April 2021 as the floats were carried by the currents. Three floats crossed Reykjanes Ridge to the west to be carried counterclockwise around Irminger Basin in a boundary current while one crossed the Iceland-Faeroe Ridge into the eastern Norwegian Sea. A total of 5821 profiles were acquired by 15 floats, 3174 during the process-study cruise and 3500 during the extended mission

The EM-APEX floats measured horizontal velocity (u, v), temperature T , salinity S and temperature-variance dissipation rate χ from surface to ~800-m depth. From these measurements, we infer buoyancy stratification, subinertial (balanced) eddy flow and shear (hence horizontal buoyancy-gradients through thermal-wind), near-inertial/semidiurnal shear

fluctuations (and hence gradient Froude number), and turbulent thermal diffusivities K_T and TKE dissipation rates ε .

Analysis and Results

EM-APEX float measurements capture the modulation of near-inertial waves by mesoscale eddies. Surface-layer near inertial waves are refracted by mesoscale vorticity-gradients (Thomas et al. 2020). The current state of our understanding of internal-wave-driven ocean turbulent mixing and its role in climate is reviewed by Whalen et al. (2020). Observed near-inertial oscillation currents are reasonably reproduced by a simple slab model given an accurate slab scale with a 3-day damping period (Girton et al. 2024).

The seasonal variability of near-inertial/semidiurnal shear and turbulence is investigated using extensive float measurements (Kunze et al. 2023). A seasonal pycnocline is eroded to 600-m depth during the fall. The remnant winter mixed-layer persists through summer. Both wind-forcing and tide/topography interactions contribute to the near-inertial band over modes 8-16. In late summer through early spring, near-inertial/semidiurnal motions are energized in the surface mixed-layer and permanent pycnocline penetrates to 800-m after late summer and fall storms. Internal-wave vertical shear variance was ~ 5 times as energetic as canonical midlatitude (GM) internal waves. Clockwise-with-depth (downward energy propagation) shear dominates over this same period while counterclockwise-with-depth (upward energy propagation) shear dominates in late spring and early summer, and is correlated with major topographic ridges. This suggests that both wind and tide are sources for near-inertial waves in the sub-Arctic North Atlantic with wind-forcing dominating during the stormy seasons. Interaction with the eddy field (effective beta) distributes boundary-forced intermediate vertical wavenumbers throughout the water column on timescales of 1-2 weeks. Comparable dissipation timescales preclude multiple surface and bottom reflections so that intermediate-wavenumber near-inertial waves are local to region and season, unlike lower latitudes. Turbulent diapycnal diffusivities K are $\sim 10^{-4} \text{ m}^2 \text{ s}^{-1}$, an order of magnitude larger than the canonical mid-latitude and exhibit factor-of-three month-to-month variability, consistent with the elevated internal-wave shear.

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- Girton, J. B., C. B. Whalen, R.-C. Lien and E. Kunze. 2024: Coherent float arrays for near-inertial wave studies. *Oceanography*, in press.
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